Relative Ages Of Lava Flows At Alba Patera, Mars

by
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Many large lava flows on the flanks of Alba Patera are astonishing in their volume and length (11). They are enormous by terrestrial standards ranging from 60 kilometers to over 500 kilometers in length. As a suite, these flows suggest tremendously voluminous and sustained eruptions, and provide dimensional boundary conditions typically a factor of 100 larger than terrestrial flows (2). One of the most striking features associated with Alba Patera is the large, radially oriented lava flows that exhibit a variety of flow morphologies. These include sheet flows, tube-fed and tube-channel flows, and undifferentiated flows (3,4,5,7).

Three groups of flows were studied; flows on the norhtwest flank, southeast flank, and the intracaldera region. Flow F4 is part of a system of complex flows located on the northwest flank of Alba Patera. The two sheet flows (F5 and F6) on the southeast flank appear to be less complex as compared to those on the northwest flank but resembles the lobate flow morphology of flow F4. Within the confines of the concentric fracture/graben system lies the central caldera complex with its intracaldera flows. Six flows (F7 to F12) were identified here and, although their dimensions are considerably smaller, they continue to exhibit lobate morphology.

Two general models have been proposed (10,14) relating observed crater densities to absolute age using crater diameters of either >1 Km or >4 Km. A review of the literature uncovers that a number of crater densities and absolute ages have been reported for Alba Patera (9,12). Within the framework of these models their data suggests a maximum absolute age for the Alba shield of 3.8-3.5 bybp (1,9,10) down to a minimum age of 2.6-1.0 bybp (1,9,14). Plescia and Saunders (1979) (12) have suggested that a transition in the types and loci of cone building volcanism occurred from about 2.0 to 1.5 bybp beginning at the time of major activity at Alba Patera (12). In contrast, Neukum and Wise (1976)(10) believe that by 3.0 bybp the major tectonic/volcanic disturbances were winding down and that by 2.5 bybp the activity was essentially over. These differences remain unresolved.

The above cited ages are for regional studies of the entire Alba shield whereas our work concerned itself with attempting to deduce the ages of the individual flows. Plotting of cumulative size-frequency distribution curves of the flows shows a general clustering of the data, except for flows F6 and F7 which are noticeably shifted vertically from the rest (Figure 1). The apparent clustering of most of the flows is an artifact of the overlapping of confidence intervals as determined from an assumed Poisson distribution (8,13,15) of the data. Crater density data was also plotted using crater diameters binned in $\sqrt{2}$ intervals (15). These data show a clustering of the flows similar to the cumulative curves with flows F6 and F7 being somewhat distinct from the rest (Figure 2).

Crater diameters measured for the flows on the flanks and intracaldera region ranged from about 100 meters to 2.82 kilometers. However, the majority measured (387 out of 411) are less than 1 kilometer in diameter. The use of a 1 kilometer datum for the determination of both relative and absolute ages has been widely used in the literature (3,6,10,13). Using this datum, two widely separated ages were determined from the cumulative size-frequency plots (Fig 1). Plotting this data against the Neukum and Wise (1976) (10) curve yielded an absolute age range of 3.9-3.3 bybp while plotting the same data against the Soderblom et al. (1974) (13) curve yielded a range of 0.8-0.1 bybp (Fig 3). Craters numbers, independent of size-frequency plots, suggest an absolute age range between 1.3 and 0.4 bybp after calibrating the data to fit the derived martian absolute age curve (for craters >4 Km) by Soderblom et al. (1974) (17).

A relative age sequence can be deduced from size-frequency distribution plots. Cumulative size-frequency distribution curves suggest that flows F6 and F7 are distinct from the apparent clustering of the other flows. The remaining flows (F4, F5, F8, F9, F10, F11, and F12) have plots that are very close with considerable overlap of their confidence intervals. It seems unlikely that any confident separation of relative ages for these flows is possible.

Like the cumulative curves above, the data arranged in $\sqrt{2}$ diameter bins to produce size-frequency distribution curves shows that flows F6 and F7 appear distinct from the others with flow F7 being the oldest. Again, a similar clustering of flows into an intermediate group is suggested. Flows F8, F11, and F12 appear to be lost in the noise typical for the smaller crater diameters less than 1 Km,

although somewhat better separated than in the cumulative curves. If the vertical displacements of curves are real, the suggested relative ages of the flows is F7 (oldest), followed by flows F10, F9, F5, F4 as intermediate, and flow F6 as the youngest. The relative age positions of flows F8, F11, and F12 remain, for the most part, undetermined.

Relative ages based on crater numbers, for craters ≥1 km intercept, suggest a sequence, oldest to youngest, of F7, F4, F10, F9, F5, and F6. Flows F8, F9, F11, and F12 are undetermined because they lack craters ≥ 1 km diameter. The smaller diameter crater numbers, of probable secondary origin, show a somewhat different sequence than above. Both data sets agree that flow F7 is the oldest and F6 the youngest. In contrast, however, the latter suggests that flow F4 is younger than both flows F10 and F9. Additionally, it allows for the placement of two of the three previously undetermined flows (F8, F11) on either side of flow F4, older and younger, respectively. The relative age of flow F12 still remains undetermined. Since two possible age sequences are suggested, depending on which data set is accepted as representative, a relative age sequence based on both data sets can be made so long as the larger diameter (≥ 1Km) data is given more weight. Thus a possible sequence, from oldest to youngest, is F7, F4, F10, F9, F8, F11, F5 and F6. Perhaps flow F12 is the youngest of all as it has the least number of craters. However, since there are no craters in either size bin, judgement as to its age will not be attempted.

Source vents, as a rule, are not clearly defined on the flanks of Alba Patera. However, some estimation of vent sequence can be made. The data suggests that the earliest vent activity was from the northeast part of the caldera complex producing flow F7. This area appears to have had recurring activity at later times as well to produce flows F10 and F9. The southeastern part of the caldra complex also became active producing lavas that fed flow F5. Perhaps simultaneous with this activity (within the scope of crater ages), lavas erupted from vents or fissures of unknown location on the northwest flank to produce flow F4. It is possible that the northwest flank flows may have erupted from a lateral vent on the patera's flank at or near the present ring fracture zone. Finally, the southeast part of the caldera became active once again to produce flow F6 (or possibly F5). Flows F8, F11 and F12 were erupted from the northern half of the caldera most likely sometime after the effusion of flow F7 but before or simultaneously with flows F10, F9 and F5. This suggests that the vents and/or fissures associated with the effusion of lavas from northern half and southeast portions of the caldera complex were perhaps operating within a relatively narrow geologic time frame. Unfortunately, high resolution delineation of vent activity beyond a rudimentary relative sequence is not possible with current crater density analysis techniques.

In summary, the lava flows discussed above probably were erupted as group during the same major volcanic episode as suggested by the close grouping of the data. Absolute ages are poorly constrained for both the individual flows and shield, due in part to disagreement as to which absolute age curve is representative for Mars. A relative age sequence is implied but lacks percision due to the closeness of the size-frequency curves. Regardless, it appears that the final stages in Alba's volcanic history were anything but quiet.

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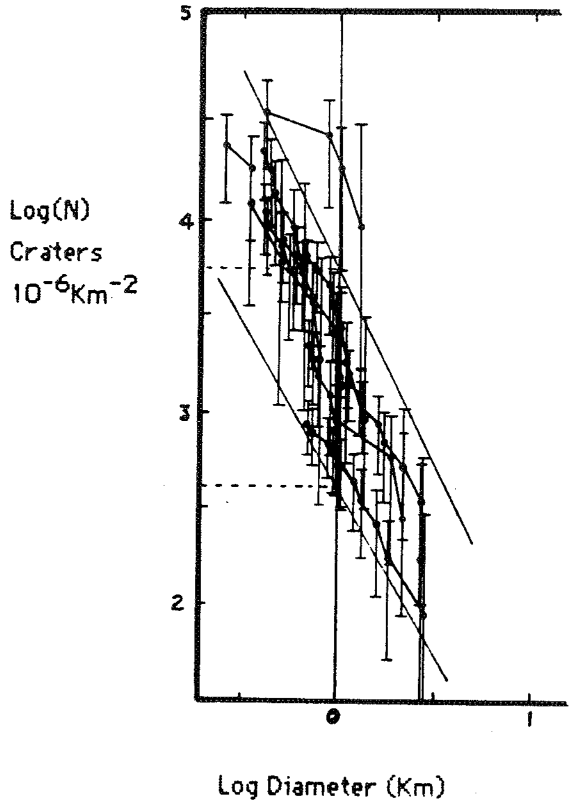

Figure 1.

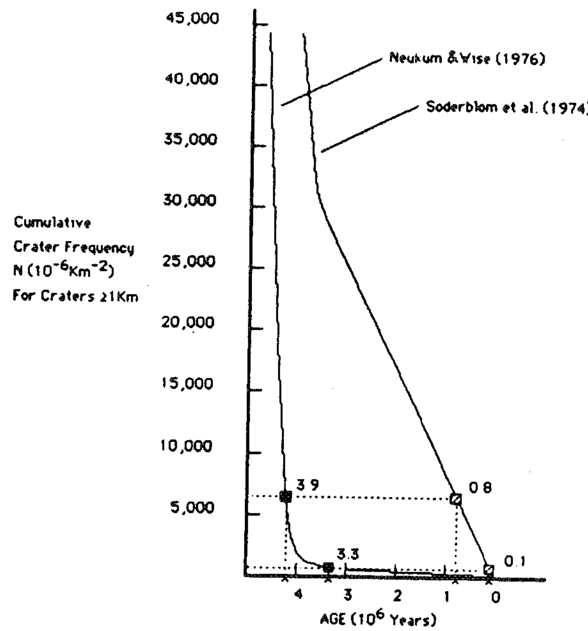

Figure 3.

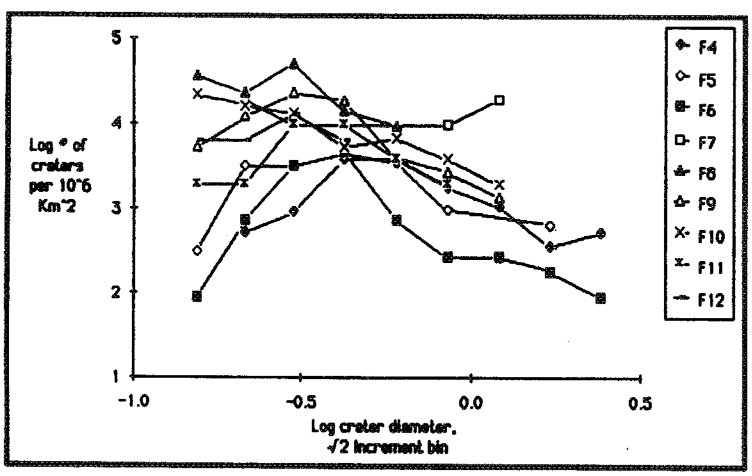

Figure 2.